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REMARKS

Claims 1-2, 5, 9, 11, 15, 17, 19, 21-22, 24-25, 27-30, 32-33 and 35-43 are all the claims presently pending in the application. Claims 3-4, 6, 10 and 12 have been canceled. Claims 1, 2, 5, 9, 11, 28-30, 32-33 and 35-36 have been amended to more particularly define the invention. Claims 39-43 have been added to claim additional features of the invention. Attached hereto is a marked-up version of the changes made to the claims by the current Amendment.

It is noted that the claim amendments are made only for more particularly pointing out the invention, and not for distinguishing the invention over the prior art, narrowing the claims or for any statutory requirements of patentability. Further, Applicant specifically states that no amendment to any claim herein should be construed as a disclaimer of any interest in or right to an equivalent of any element or feature of the amended claim.

Claims 5, 9, 11, 28-30, 32-33 and 35-36 stand rejected under 35 U.S.C. § 112, second paragraph as being indefinite. Claims 1-2, 5, 9, 11, 15, 17, 19, 21-22, 24-25, 27-30, 32-33 and 35-38 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Goetz et al. (U.S. Patent No. 6,441,393) in view of Schetzina (U.S. Patent No. 6,046,464) and Major et al. (U.S. Patent No. 6,100,546).

These rejections are respectfully traversed in view of the following discussion.

I. THE CLAIMED INVENTION

The claimed invention is directed to a light-emitting semiconductor device including a substrate, plural semiconductor layers which are made of group III nitride group compound semiconductor formed on the substrate, and an active layer comprising at least a quantum well layer which satisfies the formula $A1_{1-x}In_xN$. Importantly, a composition ratio x of indium (In) is in a range of $0.1 \leq x \leq 1$.

Conventional light-emitting semiconductor devices may include a multiple quantum well (MQW) structure having well layers formed of GaInN and barrier layers formed of GaN. However, such conventional devices experience problems. Specifically, in such devices, the performance life is short and the driving voltage (e.g., oscillation threshold) is high.

The claimed device, on the other hand, includes an active layer with at least a

quantum well layer which satisfies the formula $Al_{1-x}In_xN$, where a composition ratio x of indium (In) is in a range of $0.1 \leq x \leq 1$. As a result, the quantum well layer of the claimed device has a larger lattice constant and is softer than quantum well layers in conventional devices. Thus, the claimed device has a longer performance life and a lower driving voltage (e.g., oscillation threshold) than conventional devices.

II. THE 35 USC §112, SECOND PARAGRAPH REJECTION

Claims 5, 9, 11, 28-30, 32-33 and 35-36 stand rejected under 35 U.S.C. §112, second paragraph. Applicant notes that these claims have been amended to address the concerns of the Examiner. Therefore, Applicant submits that these claims are not indefinite.

In view of the foregoing, the Examiner is respectfully requested to reconsider and withdraw this rejection.

III. THE GOETZ, SCHETZINA AND MAJOR REFERENCES

The Examiner alleges that Goetz would have been combined with Schetzina and Major references to form the claimed invention. Applicant submits, however, that these references would not have been combined, and even if combined, the combination would not teach or suggest each and every element of the claimed invention.

Goetz discloses a semiconductor device having n-type device layers of III-V nitride, with donor dopants such as germanium (Ge), silicon (Si), tin (Sn), and/or oxygen (O), and/or p-type device layers of III-V nitride, having acceptor dopants such as magnesium (Mg), beryllium (Be), Zinc (Zn), and/or cadmium (Cd), either simultaneously or in a doping superlattice. The Goetz device is intended to engineer strain, improve conductivity, and provide longer wavelength light emission (Goetz at Abstract).

Schetzina discloses an integral heterostructure of Group III-V nitride compound semiconductors formed on a multi-component platform which includes a substrate of monocrystalline silicon carbide and a non-nitride buffer layer of monocrystalline zinc oxide. An ohmic contact may include a continuously graded layer of aluminum gallium nitride and a layer of gallium nitride or an alloy thereof on the continuously graded layer. A multiple quantum well may also be used instead of the continuously graded layer where the thickness

of the layers of gallium nitride increase across the multiple quantum well. The ohmic contacts may be used for Group III-V nitride laser diodes, light emitting diodes, electron emitters, bipolar transistors and field effect transistors (Schetzina at Abstract).

Major discloses a III-V arsenide-nitride semiconductor in which group III elements are combined with group V elements, in concentrations chosen to lattice match commercially available crystalline substrates. Epitaxial growth of these III-V crystals results in direct bandgap materials, which can be used in applications such as light emitting diodes and lasers. Varying the concentrations of the elements in the III-V materials varies the bandgaps, such that materials emitting light spanning the visible spectra, as well as mid-IR and near-UV emitters, can be created (Major at Abstract).

However, Applicant submits that these references would not have been combined as alleged by the Examiner. Indeed, these references are directed to completely different problems and objectives.

Specifically, as noted above, the Goetz device is intended to engineer strain, improve conductivity, and provide longer wavelength light emission, whereas Schetzina is directed to a device having lattice-matched substrate (Schetzina at col. 5, lines 59-61) and Major is directed to a method of growing layers that result ni an overall lattice match and desired bandgap (Major at Abstract). Thus, these references are completely different and no person of ordinary skill in the art would have considered combining the references as alleged by the Examiner, absent impermissible hindsight.

Further, Applicant submits that the Examiner can point to no motivation or suggestion in the references to urge the combination as alleged by the Examiner. Indeed, the Examiner fails to provide any support whatsoever for her allegation that these references would have been combined to form the claimed invention. Applicant respectfully submits that the Examiner must identify some motivation or suggestion to combine these references as alleged in order to support this rejection.

Moreover, none of these references teaches or suggests "*an active layer comprising at least a quantum well layer which satisfies the formula* $Al_{1-x}In_xN$, *where a composition ratio x of indium (In) is in a range of* $0.1 \leq x \leq 1$" as recited in claim 1. As noted above, unlike conventional light-emitting semiconductor devices which may include a multiple quantum

well (MQW) structure having well layers formed of GaInN and barrier layers formed of GaN, the claimed device, includes an active layer with at least a quantum well layer which satisfies the formula $Al_{1-x}In_xN$, where a composition ratio x of indium (In) is in a range of $0.1 \leq x \leq 1$ (Application at [0010]-[0013]). As a result, the quantum well layer of the claimed device has a larger lattice constant and is softer than quantum well layers in conventional devices. Thus, the claimed device has a longer performance life and a lower driving voltage (e.g., oscillation threshold) than conventional devices (Application at [0036]-[0038]).

Some principles of the claimed invention are clearly illustrated in Exhibits A and B (Figures 2 and 3, respectively) which are attached hereto and incorporated by reference herein. As set forth in the original Specification (and the priority document), Figure 2 illustrates a graph showing the relationship between In gas supplying the amount ρ (volume concentration) and the mixing ratio x of In.

In order to grow a group III nitride group compound semiconductor layer including indium (In) by crystal growth, the conditions may be fixed to a predetermined optimum condition to grow the semiconductor layer and so that the In gas supplying amount ρ may be increased. Then, as shown in Figure 2, the mixing ratio x of indium (In) in the semiconductor layer (quantum well layer) increases as the In gas supplying amount ρ increases ($\rho_b \rightarrow \rho_a$). As the composition ratio x of indium (In) increases, this reduces the likelihood that the spatial density deviation (segregation) of composition in InN will occur as shown in Figure 2.

Under such conditions, as shown in Figure 2, a quantum well layer having a high composition ratio (x_a) of indium (In) is difficult to occur due to the non-uniformity of InN composition compared with a quantum well layer having a low composition ratio (x_b) of indium (In). Accordingly, forming a quantum well layer having a high concentration ratio (x_a) of indium (In) is more advantageous.

Further, as provided in Exhibit B, Figure 3 is a graph showing the relationship between the band gap energy of a quantum well layer and the lattice constant of a semiconducting crystal. As shown in Figure 3, when a blue-light-emitting quantum well layer is formed by crystal growth, the quantum well layer is preferably made of AlInN, rather than GaInN so that the quantum well layer may have a higher composition ratio (x_a) of indium (In).

That is, for example, when a blue-light-emitting quantum well layer is formed by crystal growth, the quantum well layer is preferably made of AlInN rather than GaInN as in a conventional device, as shown in Exhibits A and B (Figures 2 and 3, respectively).

Clearly, these features are not taught or suggested by the cited references. Indeed, these references do not even disclose or suggest at least one of the problems (e.g., a high driving voltage) which the claimed invention was intended to address.

Further, Goetz merely discloses using AlInN as a material in an MQW layer. But Goetz fails to teach or suggest using $Al_{1-x}In_xN$ ($0.1 \leq x \leq 1$) in a quantum well layer of an active layer having an SQW or MQW structure.

Specifically, the Examiner relies on the passage at col. 3, lines 50-54 to support her position. Applicant notes that even assuming that this passage discloses an active layer 14 which includes AlInN, this passage clearly does not teach or suggest the novel active layer of the claimed device in which the composition ratio x of indium in $Al_{1-x}In_xN$ is in a range of $0.1 \leq x \leq 1$. Indeed, nowhere does Goetz teach or suggest such a novel active layer.

The Applicant explains that such a composition ratio is an important aspect of the claimed invention. Specifically, it is said that "[b]y adjusting the composition ratio x of the indium (In) to satisfy $0.1 \leq x \leq 1$, a light-emitting semiconductor device which emits rays (electromagnetic wave) having a desired and useful wavelength, which are mainly visible rays and include ultraviolet rays may be obtained" (Application at page 12, lines 8-11). Clearly, Goetz does not teach or suggest these novel features of the claimed invention.

Similarly, Schetzina does not teach or suggest the claimed invention, including the novel active layer in which the composition ratio x of indium in $Al_{1-x}In_xN$ is in a range of $0.1 \leq x \leq 1$. Indeed, as noted above, Schetzina is merely directed to a device with a lattice-matched substrate and is completely unrelated to the claimed invention.

Further, Schetzina only discloses the use of GaN/InN in a contact layer (Schetzina at col. 12, lines 44-46). Schetzina clearly does not teach or suggest using InN in an active layer. Therefore, Schetzina clearly does not make up for the deficiencies of Goetz.

Further, even if combined with Goetz and Schetzina, Major clearly does not teach or suggest the novel features of the claimed invention. Specifically, like Goetz and Schetzina, Major fails to teach or suggest using $Al_{1-x}In_xN$ ($0.1 \leq x \leq 1$) in a quantum well layer of an active

layer having an SQW or MQW structure.

The Examiner relies on the passage at col. 2, lines 9-24 to support her allegation that Major provides motivation for using certain materials such as AlGaInN for light emission. Applicant notes, however, that even if this passage of Major "provides motivation" for using AlGaInN for blue light emission, it does not necessarily provide motivation for combining the teaching of Major with the urged Goetz and Schetzina combination. That is, the Examiner must identify some motivation or reason to modify the Goetz and Schetzina combination with the teaching of Major. Applicant respectfully submits that such motivation is not found in any of these references to combine references as alleged by the Examiner.

Moreover, even assuming that Major discloses an active layer including AlGaInN, Major clearly does not teach or suggest an active layer including AlInN, and certainly does not teach or suggest an active layer in which the composition ratio x of indium in $Al_{1-x}In_xN$ is in a range of $0.1 \leq x \leq 1$.

In summary, in the present invention, $Al_{1-x}In_xN$ having a large indium concentration (e.g., x= 0.1 or more) may be included in a well layer of an active layer having a single quantum well (SQW) or multiple quantum well (MQW) structure, to thereby solve problems 1-3, which are described in paragraphs [0007] to [0009] in the original specification.

Especially, as shown in the attached Exhibit A (Figure 2) and in paragraphs [0034] to [0035] in the specification, when the composition ratio of indium is increased, it is understood that the deviation of composition ratio of indium hardly becomes unstable. Further, as described in paragraphs [0036] to [0037] in the specification, the indium composition ratio can be increased in the same band gap by using not GaInN, but AlInN, as shown in the attached Exhibit B (Figure 3).

As a result, the first problem disclosed in paragraph [0007] of the original specification can be solved. In addition, by using $Al_{1-x}In_xN$ ($0.1 < x \leq 1$), the composition ratio of indium becomes large and the lattice constant becomes larger in a certain band gap (see, for example, attached Figure 3). As a result, stress in the active layer is relaxed and the second problem described in paragraph [0008] of the specification is solved (e.g., see paragraph [0043]).

Accordingly, by using $Al_{1-x}In_xN$ ($0.1 < x \leq 1$) to form the well layer of the active layer,

characteristics of the light-emitting device can be remarkably improved. That cannot be seen in any of the prior art. That is, as clearly explained above, no prior art teaches or suggests using $Al_{1-x}In_xN$ $(0.1<x\leq 1)$/ AlGaInN to form the well layer in the active layer.

Further, with respect to claim 2, no prior art teaches or suggests forming the active layer by using $Al_{1-x}In_xN$ $(0.1 <x\leq 1)$. That is, the present claim 2 is at least patentable for the same reason of claim 1 explained above.

Further, in claims 28 and 35, the composition ratio x in $Al_{1-x}In_xN$ which may include a quantum well layer in the active layer, may be optimized. A most preferable range of the composition ratio x may include the range $0.15\leq x\leq 0.5$, as recited, for example, in claim 35. Such an optimum range cannot be seen in the prior art.

In addition, with respect to the barrier layer in the active layer, the preferable ranges of the composition ratio of gallium y may include one of $y=1$, $y\approx 1$, and $0.9<y\leq 1$, and the preferable ranges of indium may include one of $z=0$, $z\approx 0$, and $0\leq z<0.1$, as recited, for example, in claims 5, 9 and 11. These are preferable ranges to correspond each lattice constant of the barrier layer and a quantum well layer so that distortion does not occur.

In addition, the preferable ranges of the composition ratio x in $Al_{1-x}In_xN$ may be used to form the quantum well layer first, and then each composition ratio of AlGaInN may be used to form a quantum barrier layer so as not to generate distortion. This is clearly not disclosed by any of the prior art, including the references cited by the Examiner.

Therefore, Applicant submits that these references would not have been combined, and even if combined, the combination would not teach or suggest each and every element of the claimed invention. Therefore, the Examiner is respectfully requested to withdraw this rejection.

IV. FORMAL MATTERS AND CONCLUSION

In view of the foregoing, Applicant submits that claims 1-2, 5, 9, 11, 15, 17, 19, 21-22, 24-25, 27-30, 32-33 and 35-43, all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

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Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 4/21/03

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS:

Please cancel claims 3-4, 6, 10 and 12 without prejudice or disclaimer.

Please amend the claims to read as follows:

1. (Amended) A light-emitting semiconductor device comprising:

a substrate;

plural semiconductor layers which are made of group III nitride group compound semiconductor formed on said substrate; and

an active layer comprising at least a quantum well layer which satisfies the formula $Al_{1-x}In_xN$ [$(0<x\leq 1)$] , where a composition ratio x of indium (In) is in a range of $0.1\leq x\leq 1$.

2. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 1, [further] said active layer comprising a multiple quantum well structure in which said quantum well layer which satisfies said formula and a quantum barrier layer which satisfies the formula $Al_{1-z-y}Ga_yIn_zN$ ($0\leq y\leq 1$, $0\leq z<1$, $0\leq z+y\leq 1$) are laminated together alternately.

5. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 2, wherein a composition ratio y of gallium (Ga) in said quantum barrier layer is one of $y=1$, $y\approx 1$, and [or] $0.9<y\leq 1$.

9. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 2, wherein said composition ratio z of indium (In) in said quantum barrier layer is one of $z=0$, $z\approx 0$, and [or] $0\leq z<0.1$.

11. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 5, wherein said composition ratio z of indium (In) in said quantum barrier layer is one of $z=0$, $z\approx 0$, and [or] $0\leq z<0.1$.

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28. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 1, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.6$.

29. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 2, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.6$.

30. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 5, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.6$.

32. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 9, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.6$.

33. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 11, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.6$.

35. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 1, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.5$.

36. (Amended) A light-emitting semiconductor device using a group III nitride group compound semiconductor according to claim 2, wherein said composition ratio x of indium (In) in said quantum well layer is $0.15 \leq x \leq 0.5$.

Please add the following new claims:

- - 39. A light-emitting semiconductor device comprising:

a substrate;

a plurality of semiconductor layers formed on said substrate, said layers comprising a group III nitride group compound semiconductor; and

an active layer comprising at least one quantum well layer comprising $Al_{1-x}In_xN$, where $0.1 \leq x \leq 1$.

40. A light-emitting semiconductor device according to claim 39, wherein said active layer further comprises at least one quantum barrier layer comprising $Al_{1-z-y}Ga_yIn_zN$ ($0 \leq y \leq 1$, $0 \leq z < 1$, $0 \leq z+y \leq 1$) which is adjacent to said at least one quantum well layer.

41. A light-emitting semiconductor device according to claim 40, wherein said at least one quantum well layer comprises a plurality of quantum well layers comprising $Al_{1-x}In_xN$, where $0.1 \leq x \leq 1$, and

wherein said at least one quantum barrier layer comprises a plurality of quantum barrier layers comprising $Al_{1-z-y}Ga_yIn_zN$ ($0 \leq y \leq 1$, $0 \leq z < 1$, $0 \leq z+y \leq 1$), and alternately formed with said plurality of quantum well layers.

42. A light-emitting semiconductor device according to claim 41, wherein said plurality of quantum well layers comprises two quantum well layers having a thickness of about 4nm and comprising $Al_{0.80}In_{0.2}N$, and

wherein said plurality of quantum barrier layers comprises three quantum barrier layers having a thickness of about 6nm and comprising GaN.

43. A group III nitride group compound semiconductor device comprising:

a substrate; and

a light-emitting layer formed on said substrate, said light-emitting layer comprising:

a plurality of quantum well layers comprising $Al_{1-x}In_xN$, where $0.1 \leq x \leq 1$; and

a plurality of quantum barrier layers comprising $Al_{1-z-y}Ga_yIn_zN$ ($0 \leq y \leq 1$, $0 \leq z < 1$, $0 \leq z+y \leq 1$), which are alternately formed with said plurality of quantum well layers. - -